**SYSE 505: System Safety and Certification**
**Module 6: Fault Models and Failure Analysis Part 3**

**Project: Common Cause Failure Analysis and Cause-Consequence Analysis**

The overall system in the figure below includes three systems: Power Supply System, System 1, and System 2. System 1 and System 2 are arranged in series, and they both need the Power Supply System to operate. The internal devices of System 1 (Device 1A and Device 1B) are arranged in parallel. The internal subsystems of System 2 (Subsystem 2.1 and Subsystem 2.2) are also arranged in parallel. At the device level, Device 2A and Device 2B of Subsystem 2.1 are arranged in series, whereas Device 2C and Device 2D of Subsystem 2.2 are arranged in parallel.

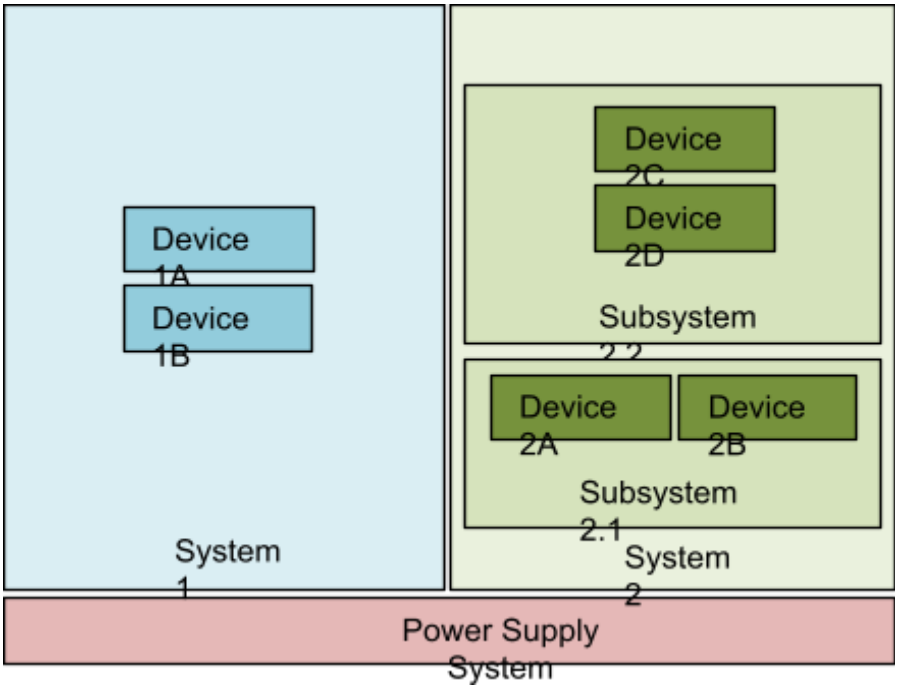


Figure 1: Block diagram of the system

In order to continue operating, the system needs the following conditions to hold:

- The Power Supply is operational, and
- System 1 is operational; System 1 operates if Device 1A or Device 1B, or both, are operational, and
- System 2 is operational; System 2 operates if Subsystem 2.1 or Subsystem 2.2, or both, are operational (i.e., Subsystem 2.1 operates if Device 2A and Device 2B are operational; Subsystem 2.2 operates if Device 2C or Device 2D, or both, are operational).

The time study period is one year, and the individual probabilities of systems/devices being in failed states are as follows:

- Power Supply: 0.005
- Device 1A: 0.025
- Device 1B: 0.025
- Device 2A: 0.001
- Device 2B: 0.001
- Device 2C: 0.025
- Device 2D: 0.025

Answer the following questions:

1) Draw the system model (Reliability Block Diagram (RBD) model).

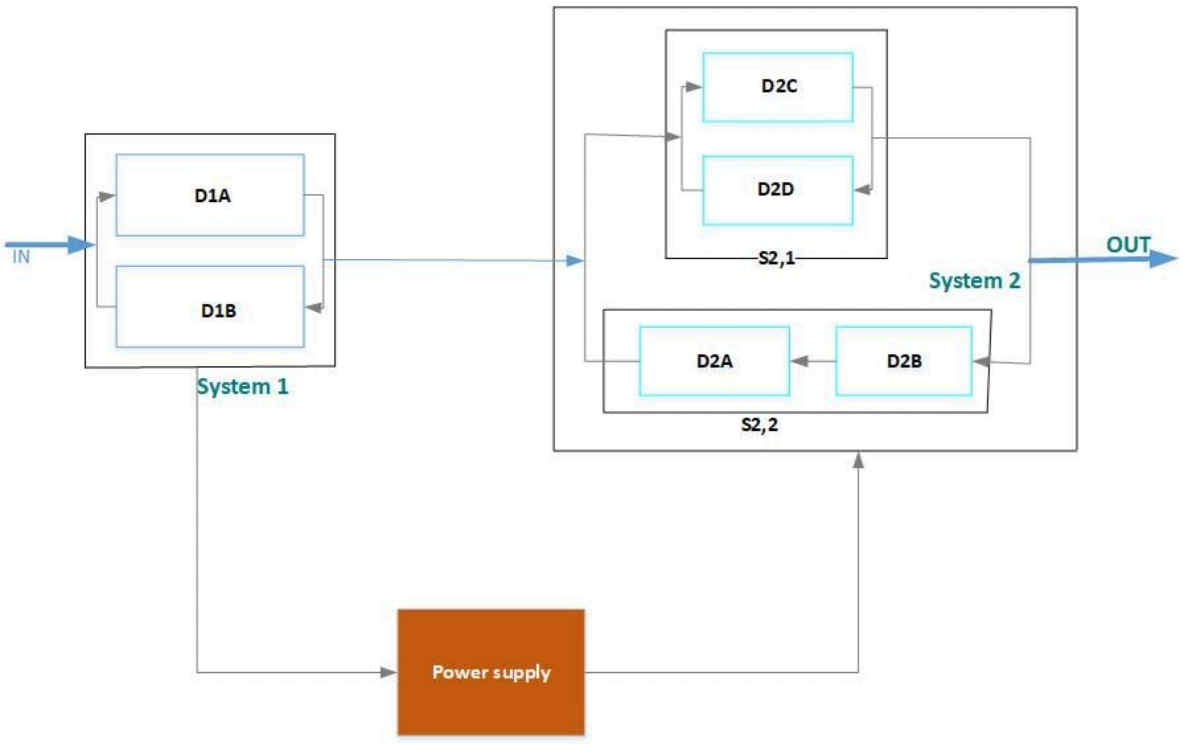


Figure 2: System model (Reliability Block Diagram (RBD) model).

2) Conduct Fault Tree Analysis (FTA) of the system by using one of the methodologies presented in the lecture notes. Calculate the resultant probability of failure for the system.

Resultant probability

$$PSR = 1-((1-pws)*(1-P_{s1\partial}*p_{s2}))$$

Let do the probability of the system separately

For system one, it is arranged

$ps1 = 1-(1-D1A)*(1-DB)$ , $ps1 = 1-(1-0.025)*(1-0.025)$ =0.0494

For system two, as shown on the reliability block diagram there are two sub system inside, so the probability will determine in such away

$Ps2 = 1-(1-Ps2.1)*(1-Ps2.2)$ but it has also anther system inside both sub systems

Subsystem 2.1 can be calculated as

$PS2.1 = 1-(1-D2C)*(1-D2D)$ , $PS2.1 = 1-(1-0.025)*(1-0.025) = 0.0494$

Subsystem 2.2 already arranged in series

$PS2.2 = D2A*D2B$ , $PS2.2 = 0.001*0.001 = 0.000001$

Therefore, the resultant of probability of system 2 yield

$Ps2 = 1-(1-0.0494)*(1-0.000001) = 0.04936$

The resultant probability of the entire system is determined from each system probability results

$$PSR = 1-((1-pws)*(1-P_{s1\partial}*p_{s2}))$$

$PSR = 1-(1-0.005)*(1-0.0494*0.04936) = 0.007487$

The probability of failed of the system is 0.007487. Therefore, the system works on the given period with less probability of failures.

3) Add potential common cause/mode failures to the fault tree and draw the resultant tree using the Common Cause Analysis (CCA) methodology. Common causes related to System 1 have a probability of occurrence of 0.001 and common causes related to System 2 have a probability of occurrence of 0.005. Calculate the resultant probability of failure for the system.

For the common cause analysis, it has an additional probability occurrence of each system.

In system one it has parallel arrangement, and also the occurrence will also parallel

$ps1 = 1-(1-D1A)*(1-DB)$ $Ps1 = 1-(1-0.025)*(1-0.025)-(1-0.001) = 0.0503$

For system 2 there are another sub system and the additional occurrence is will do the same on that system arrangement.

$Ps2 = 1-(1-0.0494)*(1-0.000001) = 0.04936$

So here it has $PS2*(1-0.005) = 0.04911$

The resultant probability on its additional probability occurrence of the system

$PSR = 1-(1-pws)*(1-0.0503)*(1-0.04911)$ then $0.1014$

4) Analyze the system using the Cause-Consequence Analysis methodology. Draw the cause-consequence diagram and the fault trees for the intermediate events. Calculate the resultant probabilities of occurrence of all possible outcomes.

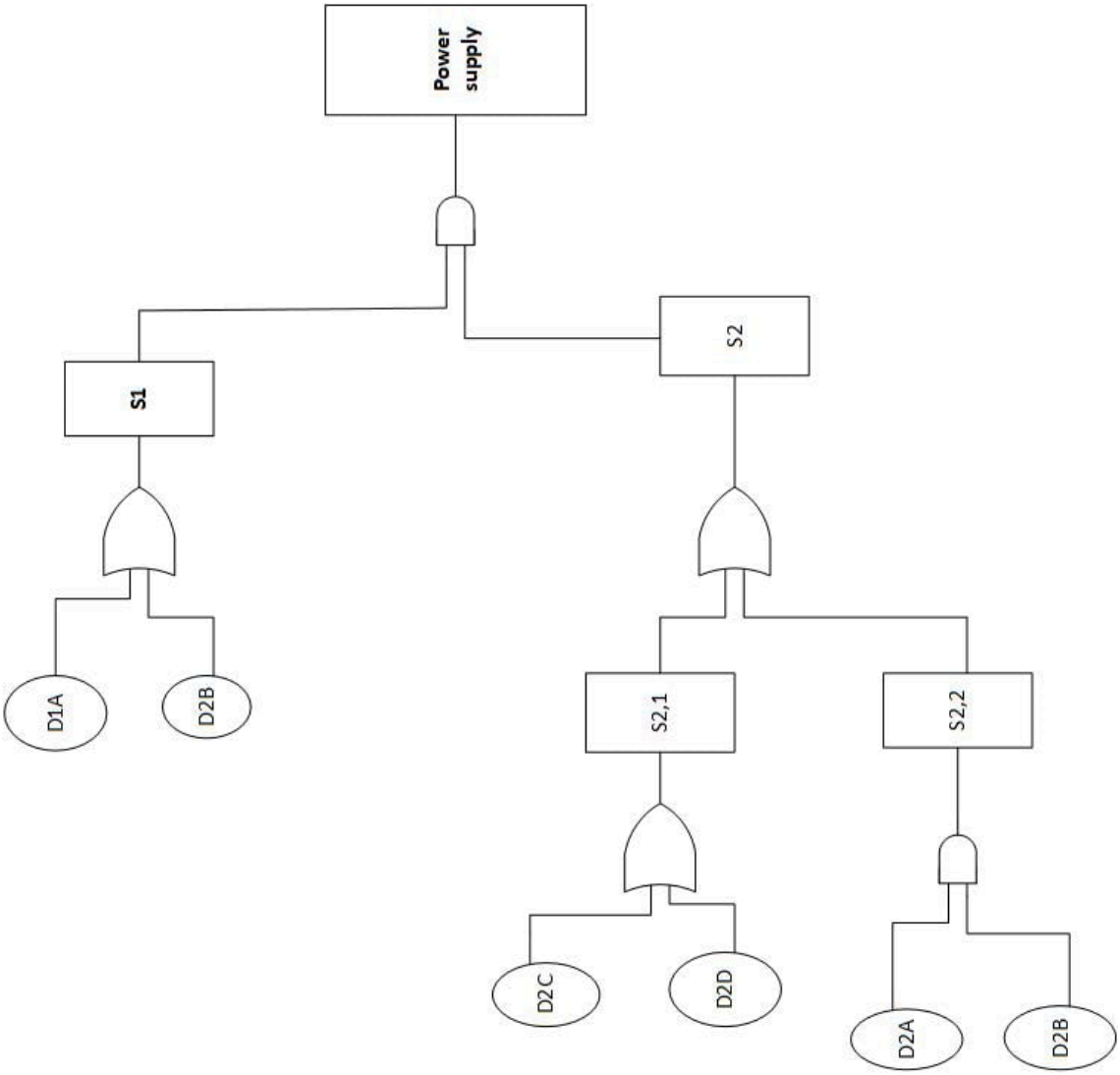


Figure 3: Cause-consequence diagram and the fault trees for the intermediate events

$$PSR = 1 - ((1 - pws) * (1 - P_{s1\partial} * p_{s2}))$$

$$PSR = 1 - (1 - 0.005) * (1 - 0.0494 * 0.04936) = 0.007487$$

5) To improve system safety, an additional identical Device 1C is added to System 1 in parallel with the other two devices 1A and 1B. Answer again to the questions 1) – 4) above and comment on the difference in the results.

6)

For question 1 for the additional device D1C and it has the RBD

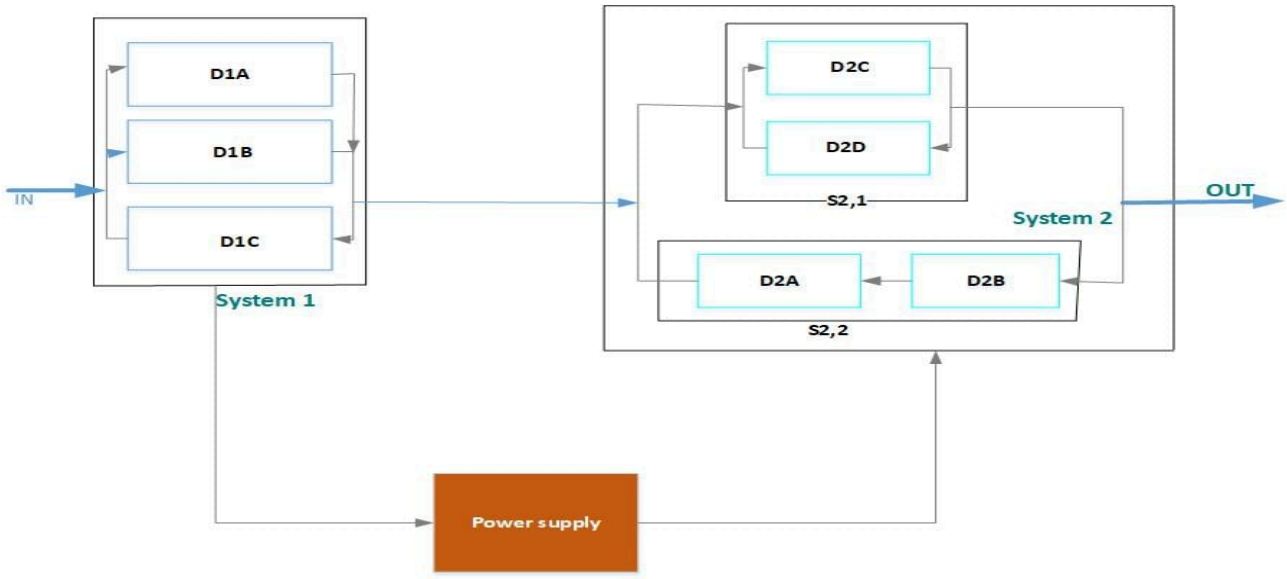


Figure 4: System model (Reliability Block Diagram (RBD) model) when additional identical Device 1C is added

For the second step the only additional device included in system 1 the other system doesn't change.

The probability is of system one

$$ps1 = 1 - (1 - 0.025) * (1 - 0.025) * (1 - 0.025) \quad = 0.0731$$

The resultant probability occurrence become

$$PSR = 1 - ((1 - pws) * (1 - P_{s1\partial} * p_{s2}))$$

$$PSR = 1 - ((1 - 0.005) * (1 - 0.0731 * 0.04936))) \quad = 0.00859$$

3, system 2 is the same on there is no additional device

We determine only system one

$$Ps1 = 1 - (1 - D1A) * (1 - D1B) * (1 - D1C) * (1 - 0.001)$$

$$Ps1 = 1 - (1 - 0.025) * (1 - 0.025) * (1 - 0.025) * (1 - 0.001) = 0.0074$$

Therefore, the resultant probability become

$PSR = 1-(1-0.005)*(1-Ps1*ps2)$ and the result become 0.005

number 4

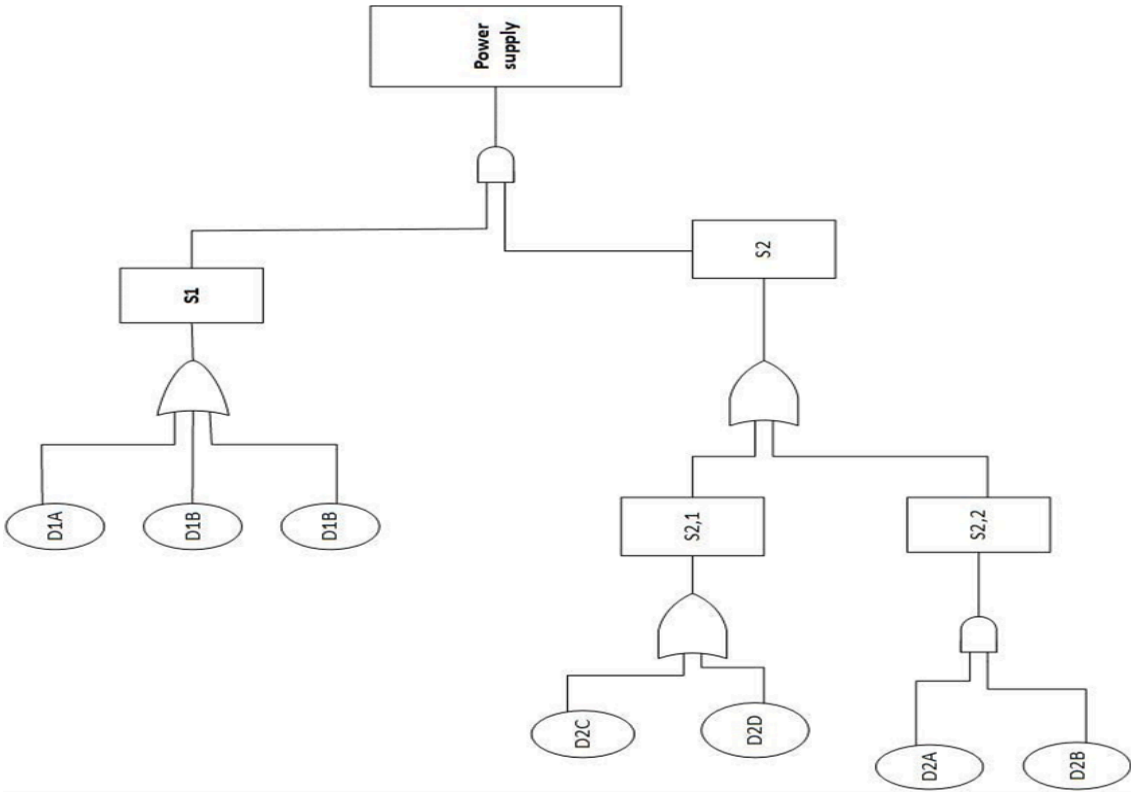


Figure 6: Cause-consequence diagram and the fault trees for the intermediate events

$ps1 = 1-(1-0.025)*(1-0.025)*(1-0.025)$ =0.0731

The resultant probability occurrence become

$PSR = 1-((1-pws)*(1-P_{s1\partial}*p_{s2}))$

$PSR = 1-((1-0.005)*(1-0.0731*0.04936))$ =0.00859